A Framework for Risk Analysis in Environmental Investments: The Restoration Project Planning Process

Ronald M. Thom[1]
Heida L. Diefenderfer[1]
Keith Hofseth[2]

[1] U.S. Department of Energy
Pacific Northwest National Laboratory
Battelle Marine Sciences Laboratory
Sequim, Washington
[2] U.S. Army Corps of Engineers
Institute for Water Resources
Alexandria, Virginia

Overview

- Develop the role of Risk Assessment in six planning steps
  - 1) Identifying problems and opportunities
  - 2) Inventory and forecast
  - 3) Plan formulation
  - 4) Evaluation of plans
  - 5) Comparison of alternatives
  - 6) Plan selection
- Demonstrate the application of this approach using an example of a tidal wetland restoration planning process

Iterative Planning Process

"We cannot overemphasize the importance of the difference between this iterative conceptualization of the process of policy analysis and the simple linear approach."
[Morgan and Henrion, 1990]

- **Effective risk analysis is an integral part of the planning process that strengthens resulting decisions**
- **Refinement and analysis of the problem statement with new information**

THE PLANNING PROCESS AND RISK ASSESSMENT ARE NOT LINEAR!

- **6 Planning Steps carried out simultaneously**
- **One comprehensive picture will develop**

Incorporating Risk Assessment into the Planning Process:

- Identify acceptable levels of uncertainty at the start of the planning process
- Use conceptual and empirical models to communicate the planning team's understanding of the ecosystem to others
- Consider the risk associated with variables chosen to measure project effects
- Manage identified uncertainty
- Use alternative designs
- Use risk information to eliminate high-risk alternatives
- Incorporate risk assessment into the Corps' four criteria of effectiveness, efficiency, completeness, and acceptability
- Consider an alternative's uncertainty along with other attributes.
- Use risk information in the final plan selection process

Risk and Uncertainty

- **Risk**
  - Negative or undesirable outcome
    - Actual harm to the environment
    - Failure to achieve the planning objectives
    - Not using the most cost-effective measure to achieve a planning objective
- **Uncertainty**
  - "a lack of sureness about something or someone."
    - Event
    - Piece of Information
    - Outcome of a Process

Two Origins of Uncertainty

- ***Inherent variability*** *("aleatory uncertainty")* the ordinary variability in a system. In nature, the irreducible randomness of natural processes. In man-made systems, the irreducible vagaries of the system. Ecosystem restoration examples: stream flow, soil properties, the success rate of propagules in revegetation.

- ***Knowledge uncertainty*** *("epistemic uncertainty")* a lack of understanding of events and processes, or a lack of data from which to draw inferences; by assumption, such lack of knowledge is reducible with further information. *Probability* is a way of quantifying uncertainty.

The Planning Process: Step 1

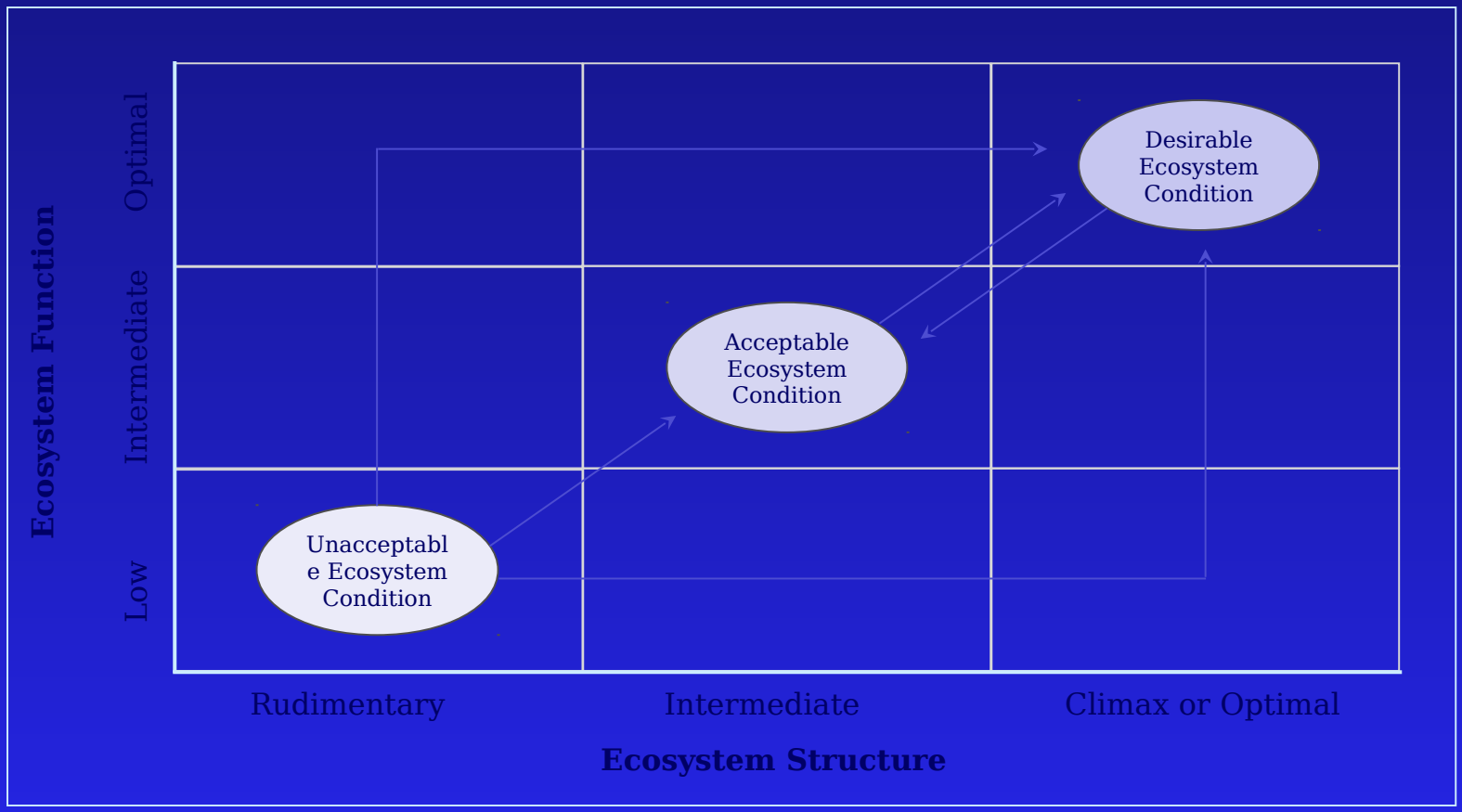
Identifying Problems and Opportunities

Civil Works Objective

- In ecosystem restoration, the civil works objective is to "*restore degraded significant ecosystem structure, function, and dynamic processes to a less degraded, more natural condition*" [ER1105-2-100].
- The federal objective becomes a goal for Corps' planners in each ecosystem restoration planning study [IWR Report 96-R-21].

Salt Marsh Restoration Example

- Planning Goal of the Project
  - Restore degraded significant salt marsh ecosystem structure, function, and dynamic processes to a less degraded, more natural condition
- Measurable Planning Objectives
  - Reestablish historical salt marsh area and achieve sustainable populations of particular bird and fish species using the habitat
- Measurable Design Objectives (examples)
  - Increased area of salt marsh
  - Increased resting, feeding, and nesting areas for waterfowl
  - Increased feeding habitat and low tide refuge for fish



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Ecosystem Performance Model

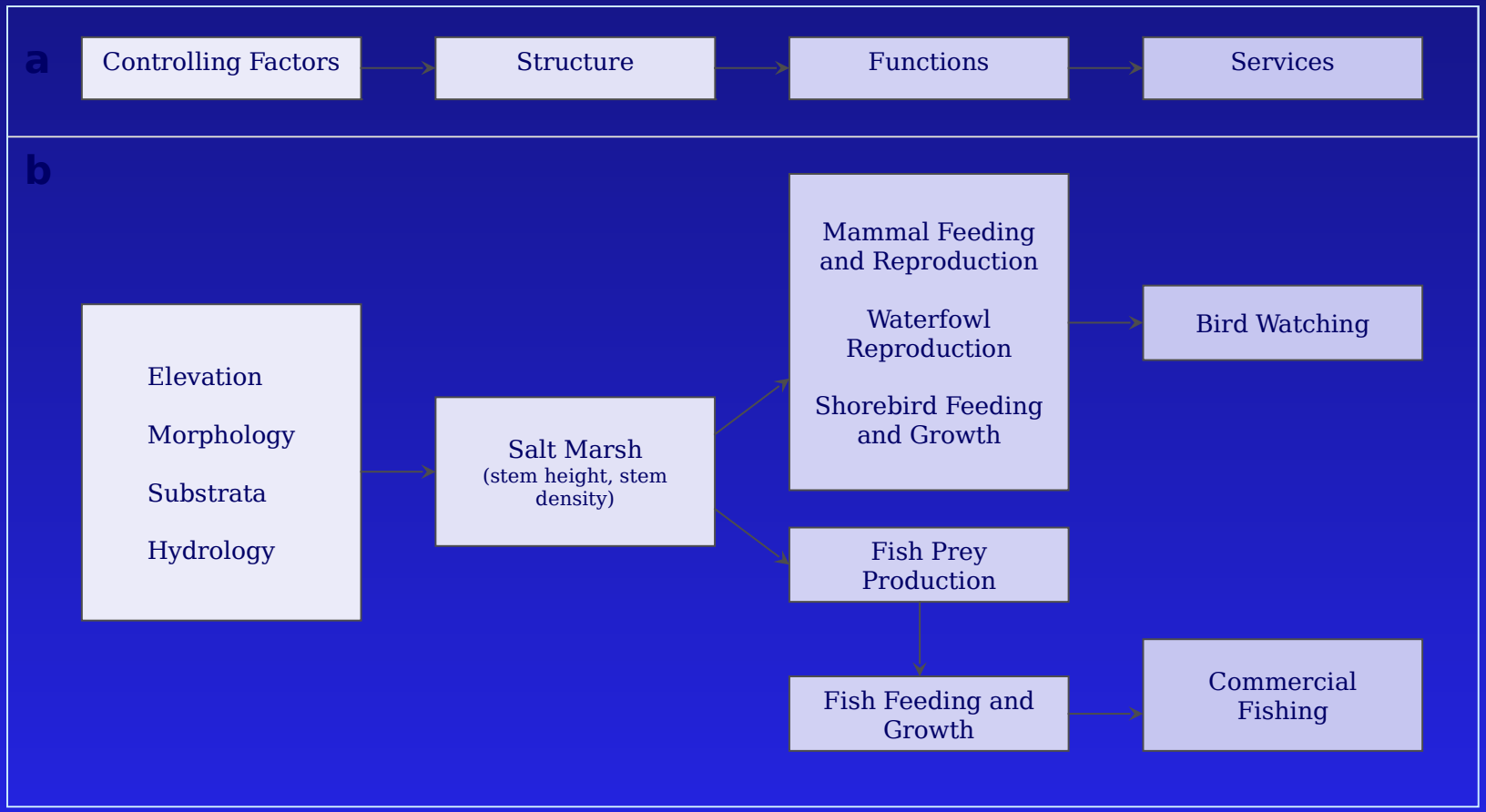
- Project goal is met if the system falls within a range of values for structure and function.
- Using a range of values acknowledges two sources of uncertainty:
  - Uncertainty about our ability to restore ecosystems (knowledge uncertainty)
  - Natural variability associated with the relationships between structural conditions and functional conditions (inherent variability)

The Planning Process: Step 2

Inventory and Forecast

Benefits of the Conceptual Model

- Enhances stakeholder participation
- Minimizes ecological risk
- Coupled with the decision process allows a systematic approach to risk and uncertainty
- Identifies the connection between the project goal and the physical and biological actions required to achieve it



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Controlling Factors: Uncertainty Assessment

- The level of certainty about the quantitative relationship between the controlling factors and the structure of the system.
- If there is a high degree of uncertainty about the relationship between a controlling factor and the structure of the system, and this factor is believed to be highly important, there is good justification for directed research into the relationship to reduce the uncertainty. Key action: identify potential causes for the degraded condition of the site.
- Site investigation might be needed to evaluate causes and to determine whether they are still contributing to the degraded condition. If they have been corrected, then there would be less uncertainty associated with restoration.

Conceptual Models Used in Restoration Planning

Several models are relevant in restoration planning:

- *Landscape Ecology Model -* important landscape elements are defined and the project is developed in this context
- *Ecosystem Model -* provides a map of the important components of the ecosystem and the ways in which they are linked
- *Habitat or Subsystem Model -* biological components and relationships with respect to a key species or function
- *Ecosystem Services Model -* couples the biological aspects of the project with social and economic aspects of the project
- *Ecosystem Performance Model -* provides the general direction that the ecosystem is expected to take on its trajectory toward meeting the project goal

All of these models can be developed at various scales.

Existing Conditions Analysis

- HSI marsh wren model indicates the quality of existing ecosystem conditions
- HGM tidal marsh model provides additional guidance to the design possibly not included in the HSI model
- Potential threats of non-native vegetation must be considered
- Existing conditions will remain indefinitely without modification to hydrology and/or removal of fill

Existing Condition Assessment

- Existing conditions are poor for wildlife and vegetation

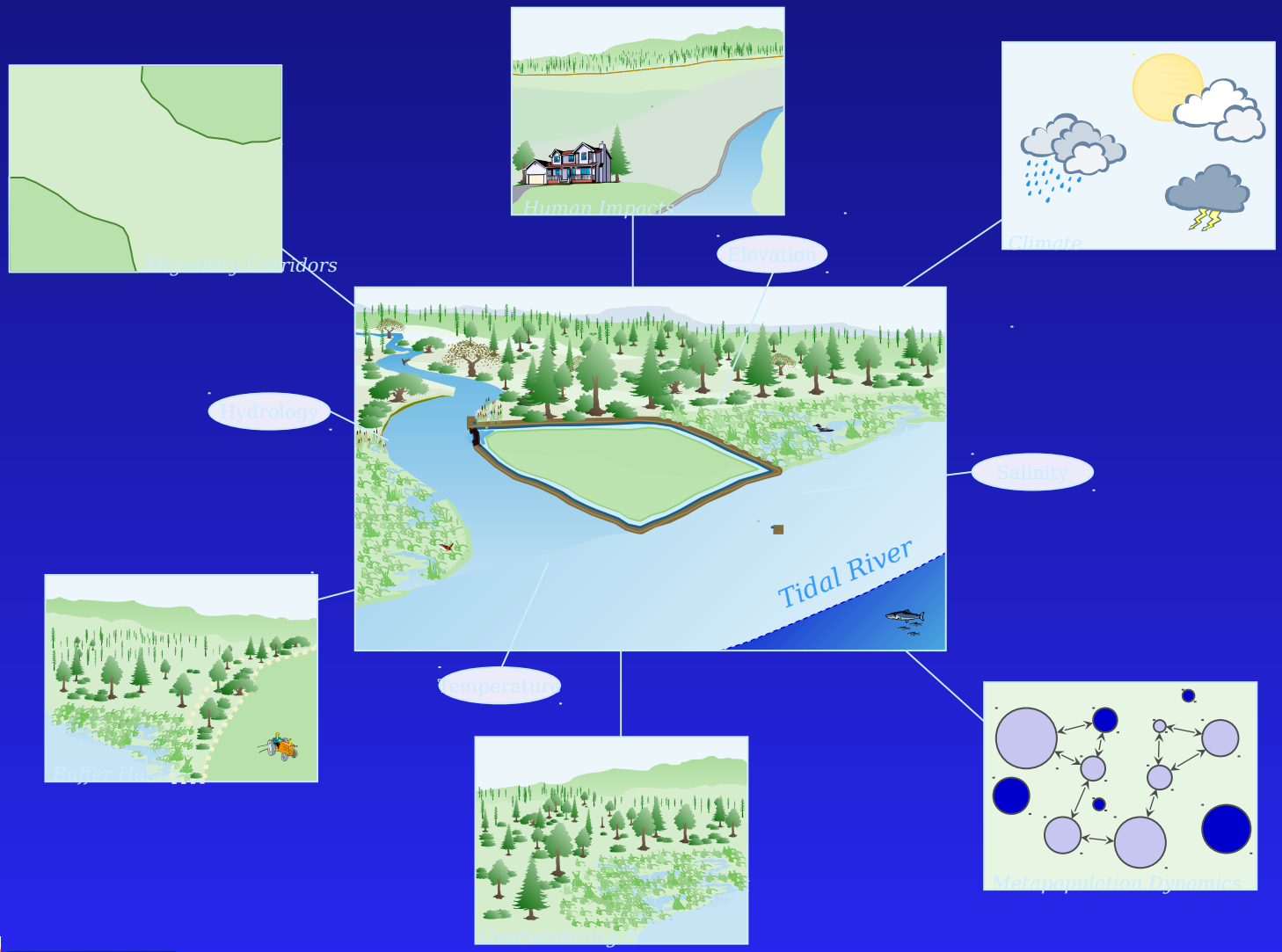
Index	Minimum	Median	Maximum
Marsh wren HSI	.00	.10	.20
WHU HGM	.00	.10	.20
PCC HGM	.00	.05	.10

The Planning Process: Step 3

Plan Formulation

The Landscape in Plan Formulation

- To conduct the risk assessment, ask questions that link the project site to the landscape and to the conceptual model that represents it:
  - What can go wrong?
  - Will there be adequate corridors?
  - How will restoration for a species affect the community?
  - Is the site large enough?
  - How will the project's resistance and resilience change over time? Is it acceptable?
  - What are the likely landscape changes over time? How will they affect the site?
  - Does the design invite invasive species?
  - How will the community affect the species of interest?



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Uncertainty in Model Selection

- HSI and HGM models – best applied at different scales
  - HSI is focused on the individual species
  - HGM integrates landscape and community scale information and general habitat use
- When HSI Models are applied to plan-formulation in ecosystem restoration projects, there is a risk that results will be extrapolated from one species to another species, or from a species to objectives at a larger scale, such as the ecosystem.
- When HGM models are used in plan-formulation, there is a risk that the unique requirements of certain species will not be adequately accommodated.

Built-in Knowledge Uncertainty

- HSI and HGM Models
  - Uncertainties derived from their basis in expert opinion
  - Incomplete data sources
  - Imperfect application of numerical equivalencies for habitat quality and functions
  - Sources of uncertainty associated with empirical quantities, because the models are based on such data; can be reduced to some degree by studies directed at data gaps

Inherent Variability

- When the HSI or HGM models are applied in plan-formulation for specific natural or man-made systems, inherent variability may affect the outcome of the project in unpredictable ways
  - Example - a major storm event occurring within months of a restoration planting effort, when plants are particularly susceptible to damage
- As a general rule, it is possible to reduce the knowledge uncertainty, but impossible to reduce inherent variability

The Planning Process: Step 4

Evaluation of Plans

Evaluation of Plans

- Identify all potential significant effects of each plan
- Broaden the focus to the watershed or landscape level
- Consider both the conceptual and empirical models to evaluate the system and examine the possibility of unintended or incidental consequences
- When the variables being used to measure the effects on the planning objectives are determined to encompass all significant effects – the evaluation process may proceed

Habitat Value Scores

- Estimates take the distribution rather than individual point estimates as the input for each variable in the model
  - Monte Carlo processes combine the input distribution for each variable into the distribution of habitat units

(PCC)

- Vcov Uncertainties: grazing, natural colonization, proximity of seed sources, disturbance
- Vexotic: percentage of cover of exotic and nuisance species
  - Seed source proximity
  - Grazer preferences

Variable[a]	Alternative 1 Index			Alternative 2 Index			Alternative 3 Index			Alternative 4 Index			Alternative 5 Index		
	Most likely	min	max	most likely	min	max	most likely	min	max	most likely	min	max	most likely	min	max
Vcov	0.9	0.2	0.99	0.85	0.1	0.99	0.95	0.4	0.99	0.9	0.2	0.99	0.95	0.4	0.99
Vexotic	0.2	0.01	0.99	0.2	0.01	0.99	0.2	0.01	0.99	0.2	0.01	0.99	0.2	0.01	0.99

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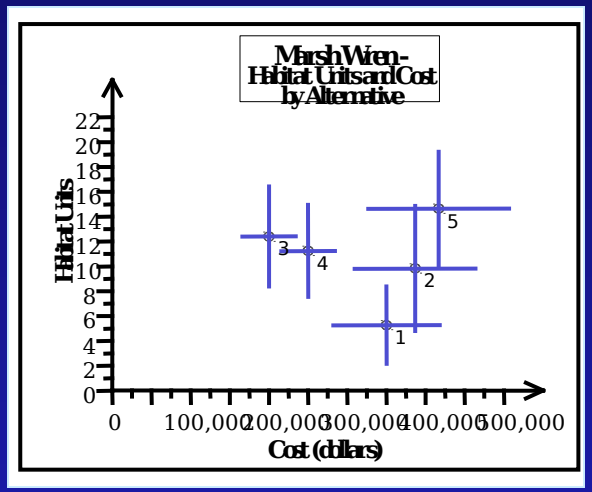
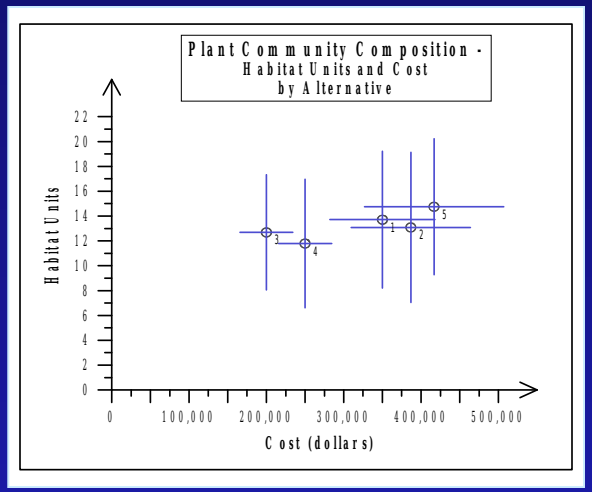
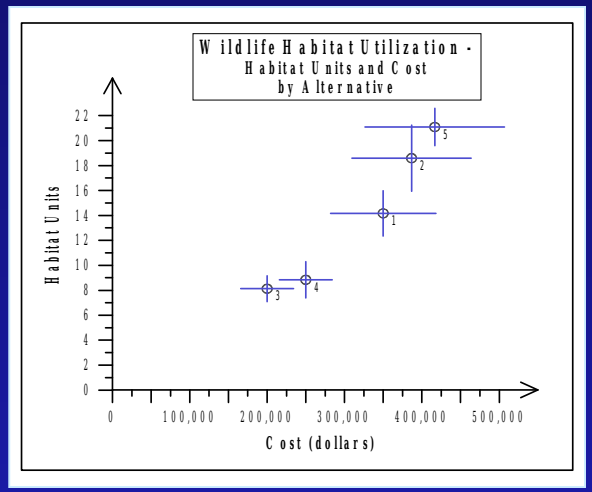
Alternatives to Develop

- Removal of dike and fill
- Removal of dike and fill with planting of desirable species and grazing prevention.
- Removal of fill only with planting of desirable species and grazing prevention. The tide gate will be modified to regulate water depths.
- Removal of fill, planting of desirable species, grazing prevention, and partial removal of the dike to allow robust environment for vegetative stand to develop.
- Removal of fill, planting of desirable species, grazing prevention and removal of the dike in segments over time to allow robust environment for vegetative stand to develop and achieve a completely natural tidal wetland environment.







- The final decision will depend on the relative weight assigned to each model score
- "Acceptability" can be assessed by the risk information revealed in the analysis
- Cost of an alternative may be prohibitive
  - Example: Alternative 5 risks exceeding a budget of $450,000
- **Further consideration – Alternatives 2, 3, and 5**

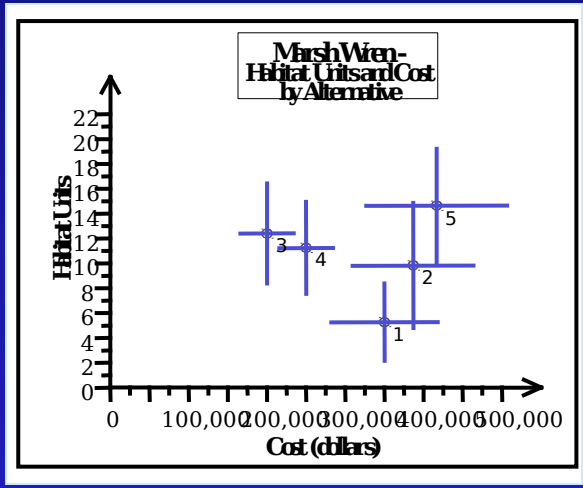
The Planning Process: Step 5

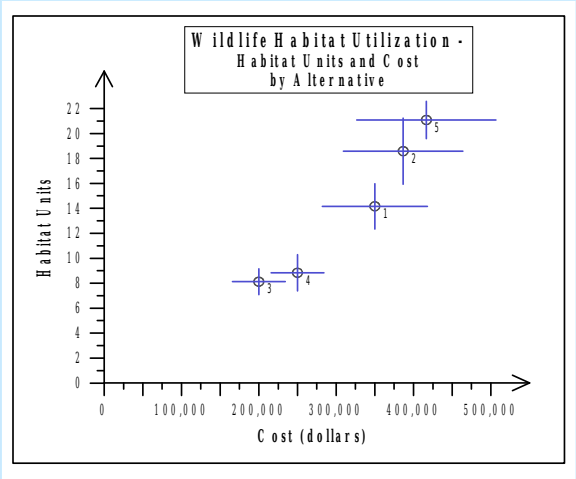
Comparison of Alternatives

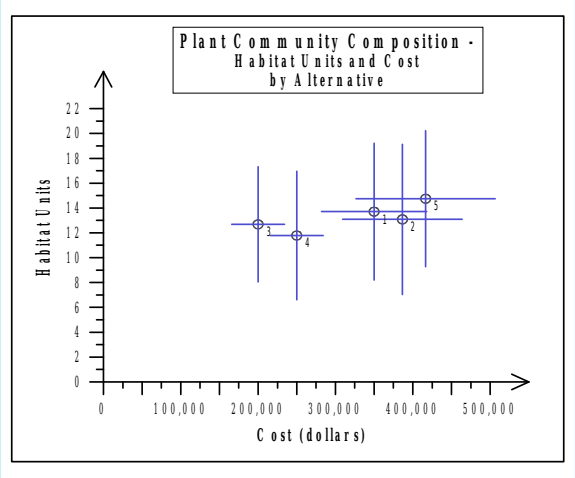
Including Uncertainty in the Analysis

- Comparison of the overlapping ranges of potential outcomes for each alternative
- Not a simple examination of the alternatives at their mean values
  - This method allows alternatives that may be dominated by other alternatives at the mean to be included in the final choice set

Overview of Cost Metrics







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The Planning Process: Step 6

Plan Selection

Remaining Plans

- All remaining plans, including the no-action plan, are equally rational choices given the metrics of the planning objectives
- The “best” choice is the one that maximizes general welfare
  - without commensurate outputs or market prices for such outputs, there is no objective way to identify this alternative
- One of the most important parts of plan-selection is a convincing rationale

Step 6: Plan Selection

- Final choice set in this example consists of Alternatives 3, 5, and the no-action plan
  - All three options can be defended
- No-action is the least expensive – other alternatives may be too expensive for the outcome achieved
- Alternative 3 has similar accomplishments on the marsh wren and PCC metrics for less than half the cost of Alternative 5
- Alternative 5 makes a significant contribution to the WHU index and is higher than all other alternatives in Marsh Wren Habitat Unit and PCC scores
- Alternative 3 leaves the man-made levees and tide gate in place – does not directly reflect a natural system
- Subjective values brought to the analysis by the decision-makers will determine the final selection

Final Selection

- Risk exists that the metrics used to measure the contribution of a plan to the planning objectives do not fully reflect the stated goals of the planning effort – Example: Corps' restoration program goal to reestablish natural self-regulating systems not reflected in index- Alternative 5 selected in this example by the planning team
  - Significant contribution to the WHU index
  - Completely restores the site to a more natural condition
- Cost is more than double Alternative 3
  - May not be worth the incremental gain
  - Finances may be utilized to restore a different site
- After the planning team has made its recommendation, decision-makers such as Corps' leadership, local sponsors, and stakeholders make the final judgment

Planning Objective Proxy Measure

- Tidal wildlife habitat and tidal wetland vegetation communities quantified using the HSI model and the wildlife utilization HGM model
- Use of both models accounts for both the important species of concern and general wildlife conditions at the site
- HGM model also provides a simple and direct measure of the amount of native vegetation cover relative to non-native vegetation cover